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RESEARCH PAPER

A Critical Overview of Forestry Seedling Production Policies and Practices in Relation to Smallholder Forestry in Developing Countries

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Abstract This paper reviews forestry seedling production systems in South-east and East Asia and identifies problems with respect to seedling quality, seedling distribution and financial sustainability, and measures which have been adopted or advocated to improve performance in this sector. The paper draws in particular on experience in a series of research projects on smallholder forestry in the Philippines. Some observations are also drawn from the following papers in this combined special issue of *Small-scale Forestry*. It is found that a mix of public and private sector models are adopted for forestry seedling production, between and even within countries. Often nurseries are set up to provide seedlings for a government-directed expansion in tree planting, and have difficulty surviving once the initial planting purpose is completed. Private nurseries often lack resources, and depend on contracts to supply seedlings for financial viability. Demand tends to be highest for fast-growing species (often exotics), fruit trees, and ornamentals in the case of urban nurseries. Government policies typically favour quantity over quality of the seedlings produced. Considerable scope exists for adopting best or at least improved management practice in seedling nurseries.

Keywords Germplasm · Forest reproductive materials · Seed pathway · Community forestry · Crowding out

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Introduction

The high rate of deforestation in many developing countries has led to logging controls on native forests and the promotion of plantation forestry. Plantation forests have been established using industrial forestry models, and more recently, increasingly through community-based forest management and by smallholders. Governments and companies managing industrial plantation estates have typically set up nurseries for their own seedling needs, sometimes with sale or free distribution of excess seedlings to local smallholders. However, there has been a movement away from industrial plantings, some of the reasons for which are discussed by Harrison and Herbohn (2003). This has resulted in increasing demand for seedlings for smallholder *tree farms*, in the form of agroforestry, compact block, boundary and other planting formations.

As logging controls have been introduced and tightened in various developing countries, and traditional log sources have become unavailable to the timber industry, there has been increasing reliance on sawn timber imports and on locally grown plantation timber. The importance of replacing both logs sourced from natural forests and timber imports has been recognized in developing countries. However, the progress in forestry expansion—and especially smallholder forestry—in these countries is typically slow, and is confronted by many obstacles. Byron (2001) noted that one of the keys to success of farm forestry has been 'a viable production technology'.[1] A major element of this technology concerns the production of high quality seedlings. Taking a similar approach, Killin et al. (2002) noted eight keys to forest expansion to support regional development in north Queensland, Australia, one of these being research to support genetic improvement of forestry tree species.

Tree planting typically has major environmental benefits or externalities, beyond the private benefits to tree growers, hence the rate of planting tends to be less than optimal, a case of market failure which potentially can be corrected by government intervention. Promotion of smallholder forestry by governments is widespread in developing countries, including South-east and East Asia, to correct this market failure and also as a livelihood support measure. Provision of free seedlings by government is a common support measure, which is practiced for example by the Department of Environment and Natural Resources (DENR) in the Philippines (Gregorio et al. 2005, Gregorio et al. this issue) and the Royal Forest Department (RFD) in Thailand (Elliot and Kuaraksa, this issue).

Often, government initiatives are introduced which involve a large ramping up of seedling production for timber trees, such as the nationwide project Project 661 (the Five Million Hectares Project, 5MH) in Vietnam, the Greening Philippines Program (or Trees for Life Program) in the Philippines (reported by Gregorio et al. and also Mercado and Duque-Piñon, this issue), and the recent initiative of the Forest Ministry of Indonesia to plant 79 M trees before the 2007 United Nations climate

[1] Byron's other three keys are: secure property rights to land and tree crops; capacity for crop protection; and adequate markets.

change conference.[2] These grand planting programs require huge numbers of seedlings to be produced, the majority typically being from government nurseries.

A well functioning forestry seedling nursery sector is essential for plantation expansion, seedling production being a critical first step in the timber supply chain. It is necessary to understand the current systems of government and private nurseries, and constraints and problems experienced in seedling production, to be able to identify measures to improve seedling production, from a government policy and nursery management viewpoint. Research into seedling production in Regions 8 and 10 of the Philippines is being carried out under the ACIAR seedling enhancement project.[3] Production of the combined special issue of *Small-scale Forestry* (SSFO) is also motivated by recognition of the need to understand seedling production systems, and to draw on experience in various countries.

This paper provides a synthesis of the issues facing the forestry seedling production sector in developing countries, and of measures to overcome or ameliorate problems in the sector, with particular emphasis on experiences in research projects in the Philippines. In terms of research method, the paper draws on experience in ACIAR projects in the Philippines, visits to other countries in the region to examine seedling production systems, published literature (including papers prepared for this issue of *Small-scale Forestry*), and more general literature sources in journals and the 'gray literature'. The next section briefly summarises the themes of the various papers in this issue of the journal. The various characteristics observed in seedling nursery systems are then reviewed. Major problems which have been identified in seedling production are summarized. Finally, measures to overcome these problems, including policy implications, are discussed.

Papers in this Issue

The special issues contain a number of regular submissions to SSFO, as well as invited papers, on forestry seedling production systems. The strong interest in this topic lead to expansion to two issues. The following 13 papers address a variety as aspects of seedling nursery systems in developing countries.

Two papers report on forestry nursery ownership and operations in a specific region. Mercado and Duque-Piñon examine the state of the smallholder seedling nursery sector in Mindanao, the Philippines, where there has been considerable industrial and private forestry activity in recent years. Gregorio et al. report research on the government nursery sector in Leyte in the Philippines, which is the major source of seedlings for smallholders. The relationship between government, community and

[2] According to the Global Warming is Real (2008), Indonesian officials on 28 November 2007 reported that 79 million trees were planted in a single day in an effort to replant lost forest cover and signal how seriously the government views the problem of climate change. This took place shortly before the United Nations climate change conference in Bali of 3–14 December. NPR Foundation (2008) noted that the move is part of a United Nations campaign to plant a billion trees around the world.

[3] Formally, this is ACIAR project *ASEM/2006/091—Enhancing tree seedling supply via economic and policy changes in the Philippines nursery sector.*

private nurseries is examined, as well as ways in which the government sector could support rather than compete with community and private nurseries.

Two papers address constraints on expansion of urban nurseries. Babalola examines the role of small-scale private urban nurseries in Ibadan, Oyo state, Nigeria, and factors which could support further development of the nursery sector, drawing on findings from a nursery survey. These nurseries produce seedlings of timber trees (including eucalypts, teak, conifers and gmelina), although landscaping and maintenance of private gardens are their most important activities. Ahmed et al. also report a survey-based study of urban nurseries, in Sylhet town in Bangladesh, but find greater emphasis on production of forestry seedlings, including acacias, mahogany and teak. Both of these studies identify access to land as a constraint to nursery establishment.

The use of traditional practices in seedling production in remote communities is examined in two papers. Roshetko et al. evaluate indigenous practices for germinating seed of Petai (*Parkia speciosa* L.), including seed shelling and seed cutting. Seed shelling is found to achieve accelerated germination but does increase the germination rate or seedling growth. Seed cutting treatments also accelerate germination, but reduce seedling diameter and height growth and in combination with no shelling may increase seedling mortality. Farmers concerns to retain part of the seeds for household use can be addressed by selecting the largest and best seed for propagation and using the rest for consumption. The use of traditional practices in seedling production in remote upland areas in Leyte in the Philippines is examined by Bernaldez and Mangaoang. They note the lack of seedling nurseries in upland areas, and the widespread use of wildlings, as well as domestication of naturally regenerated trees.

Surata and Butar Butar report experimental work to determine optimal shading in sandalwood seedling nurseries in Timor in Indonesia, where wet conditions can lead to high seedling mortality. Corrugated plastic roofing (laserslip) resulted the greatest growth in height and diameter and greatest survival percentage of sandalwood seedlings, followed by paranet, transparent plastic, coconut leaf, imperata grass and the traditional shade house.

Kadda et al. compare the relative merits of centralized nurseries as against smaller individually owned and operated nurseries for the production of seedlings of biofuel energy crops in Negros Occidental in the Philippines, concluding that there are cost advantages of the former.

Two papers address issues in the forest tree seed supply chain. Roshetko et al. describe well-developed seed pathways in Java, which provides a model for other developing countries in south-east Asia. Much of the tree seed collection takes place in the Wonogiri-Ponorogo area, where seeds are collected by farmers under contract with seed assemblers or seed companies. Assemblers link farmer collectors with seed companies and middlemen, who sell seed to customers, especially government agencies. Catacutan et al. review the fluctuating fortunes of the Agroforestry Tree Seeds Association of Lantapan in Mindanao, the Philippines, as a case study in collective action by smallholders. ATSAL was particularly successful when supported by the World Agroforestry Centre, with dedicated office bearers, and with sales mainly in Mindanao. Attempts to widen the market to other areas in the

Philippines, and loss of key staff and institutional support, led to a contraction of activities, with some members taking over part of the role of the group for individual business activity.

Two papers report the use of seedling nurseries for forest conservation efforts. A case study in development of community nurseries to support conservation of rare conifer species in Vietnam is described by Morris and Hieu. These nurseries face difficulties in securing market outlets, given the focus on production forestry using exotic species in Vietnam and the limited budgets of conservation agencies to purchase seedlings. Elliot and Kuaraksa describe the role of a forestry restoration unit in Thailand in collecting seed of a large number of native tree species from a national park in Thailand, and producing seedlings to be planted by the indigenous community within the park.

The effectiveness of forestry extension measures in improving nursery seedling production efforts is examined by Baynes and Gregorio. These authors report details of an extension program supported by the Australian Centre for International Agricultural Research (ACIAR) which has attempted to increase the capability and confidence of smallholders in producing seedlings in home nurseries. The research reveals that extended training and follow-up assistance is critical to their success.

Characteristics of Seedling Production Systems in Developing Countries

A wide diversity of characteristics of seedling production systems may be identified, as indicated in Table 1. While the main division in forestry nursery ownership is

Table 1 Some characteristics of seedling production systems

Characteristic	Examples
Nursery ownership	Government, community, private (including smallholder and household nurseries)
Location	Rural, urban
Purpose for establishment	General purpose, or linked to a specific industrial, smallholder or restoration forestry project
Type of activity conducted	Production of seedlings for timber trees and fruit trees, restoration plantings, conservation of rare species, production of non-timber species (e.g. bamboo, rattan, ornamentals), landscaping and garden management
Types of timber tree species	Indigenous, exotic
Seed source	Locally collected seeds and wildlings, seed merchants (drawing on seed collectors, seed orchards, hedge gardens for clonal propagation, seed imports)
Production volume	A few hundred up to millions of seedlings per year
Technology level	Primitive, traditional, moderate or high technology (particularly tissue culture laboratories)
Pricing policy	Free, subsidized or market-based, usually with the recipient to meet the transport cost
Business arrangement	Stand-alone, integrated with other firms or nurseries
Continuity of operation	Continuous, intermittent based on seedling demand, project specific (defined life span)

between government and private owners, forestry nurseries are also set up for community forestry projects, such as the Philippine community based forest management (CBFM) projects. Private nurseries can be further divided into commercial operations, and smallholder or household nurseries which mainly produce seedlings for their own use (Mercado and Duque-Piñon, this issue).

Nurseries which concentrate on production of seedlings of timber trees often also produce seedlings for permanent restoration plantings. Also, they frequently produce fruit tree seedlings, for which there is typically high demand by smallholders, and which in some countries also make a substantial contribution to local timber supply. Particularly when located in urban areas, a substantial proportion of seedlings produced may be landscaping trees and ornamentals.

Opinion is often divided about whether production forest policy should favour indigenous (native) or exotic species. There are some sound reasons for growing indigenous species, in terms of adaptation to planting sites, high timber quality, resistance to pests and diseases, and support for wildlife habitat. However, typically exotics—notably teak (*Tectona grandis*), eucalypts, mahogany (*Swietenia* spp.), acacias and gmelina (*Gmelina arborea*)—grow more rapidly and present a better commercial proposition, and are the most widely grown.

Seeds or wildlings may be collected locally by the nursery operators from naturally growing trees and tree plantations, though sometimes seed orchards or hedge gardens for producing cuttings are set up. Sometimes there is trade in domestically produced and imported seed.

The level of technology varies greatly from very simple structures of household and farm nurseries particularly in remote locations using bamboo, coconut leaves and other temporary materials, to modern high-technology nurseries, of government departments and research centres, timber companies, and some academic institutions.

Where private forestry is an 'infant' or establishing industry, seedlings may be provided without charge or at a subsidized price to smallholders by government or industrial forestry enterprises. Sometimes relatively large private seedling nurseries operate alongside free seedling distribution of government, this being the case for example in Thailand where the RFD and the Forest Industry Organization (FIO) both operate a number of forestry seedling nurseries (Elliot and Kuaraksa, this issue).

Seedling nurseries are most often stand-alone business enterprises, but sometimes they are part of a wider government or industrial organization. Forestry nurseries can also be found which operate at multiple sites as horizontally or vertically integrated operations, as observed by Mercado and Duque-Piñon (this issue).

Seedling nurseries are a form of business undertaking which is easy to set up—the barriers to entry are relatively weak—but there is also a high rate of failure of new nursery businesses, and project-specific nurseries often close after meeting their designed purpose. In some cases, nurseries are ephemeral in operation, remaining dormant when there is little seedling demand but resuming operation quickly when a seedling market arises.

Constraints and Problems in Seedling Nursery Operations

A wide variety of constraints and problems can be identified in the forestry nursery sector in developing countries, particularly but not limited to small-scale nurseries. This section summarizes problems in seedling nurseries, pinpoints some of the causes of low seedling quality and identifies some of the more general problems in the seedling sector. This analysis does not cover out-planting and management of seedlings by tree farmers.

Common problems experienced in small seedling nurseries

Individuals and communities that set up small nurseries generally lack resources, in terms of suitable land, finance for nursery establishment, human resources (management skills) and information resources, and sometimes a reliable water supply (Table 2). Seed germination rates and seedling survival rates in the nursery may be low for various reasons. Also, research evidence reveals a pervasive problem of low seedling quality, in terms of root deformities and lack of sturdiness, e.g. Gregorio et al. (2004a, Gregorio et al. this issue), Baynes and Gregorio (this issue), Kadda (this issue).

Small nurseries have low throughput (often not more than a few thousand seedlings a year). Various factors can contribute to high production cost per seedling, including lack of negotiating power with supplies, inability to employ latest technology and hire skilled staff, inability to afford labour-saving equipment, and limited ability to advertise and to obtain sales contracts. The extent of

Table 2 Problems in seedling nurseries

Problem area	Specific problems
Lack or resources for nursery construction and operation	Inadequate land, finance, water supply
	Lack of nursery operation skills of owner and staff
Low germination rate or seedling survival	Low seed quality or poor storage facilities or method
	Insufficient water supply or watering
	Poor germination medium and potting mix
	Inadequate plant protection (from pests and diseases, cattle, windstorms)
Low seedling quality	Low genetic quality seed, poor seed collection
	Poor nursery design or operation
Low production volume	Limited to a single batch of seedlings per year, scarcity of seed of desired species
Low market prices for seedlings	Potential customers not aware of the nursery operation
	Inability to produce some species in high demand
	Timing of seedlings not matching timing of demand
Low nursery profitability	Low regular demand
	Lack of sales contracts
	Lack of economies of size in nurseries

economies of size in seedling production is not clear, since small nurseries have low overhead costs and use mainly unpriced resources, and it is possible that approximately similar production costs exist over a wide range of nursery production volumes. Further research is needed to estimate the long-run average cost of seedling production over a range of output levels, and the percentage of costs accounted for by infrastructure (overheads), labour, and materials (potting medium, purchased inputs). Such financial modelling work is in process in the ACIAR seedling enhancement project to examine size or scale economies.

It would appear that in general forestry nurseries in developing countries only produce one batch of seedlings a year, timed to be available at the commencement of the wet season, when the highest survival rate on out-planting can be expected. Given that seedlings can be ready for sale in about six to 12 weeks after planting, this means that the nursery facilities are inactive or carrying leftover stock for most of the year.

Evidence suggests small community and private nurseries are unlikely to evolve into commercial enterprises (Estoria et al. 2004; Harrison et al. 2008a, b). High failure rate of new business enterprises is a common phenomena, and it is a valid question to ask whether:

- short nursery life is mainly due to their one-off seedling production requirement,
- financial failure is a natural state for an 'easy to enter' industry, with a low capital requirement, or
- nurseries fail due to inadequate resources, lack of support or poor decision making, such that the survival rate is amenable to improvement.

The conditions for survival can be astute management, adequate resourcing and site and product or process advantages. As demonstrated by Morris and Hieu in this issue, nurseries are critically dependent on seedling demand from the government or private growers. Securing contracts to supply seedlings can be a critical factor in short-term progress, but the business still needs to be able to stand on its own feet when such contracts run out. A nursery setup to take advantage of a regular demand for seedlings could be expected to have a greater chance of success than one reliant on occasional large orders.

Causes of Low Seedling Quality

It may be hypothesized that low quality seedlings lead to low quality trees, typically with low growth rates and poor form. For instance field observations indicate that gmelina trees grown in Leyte are generally of poor form, which may be due to low genetic quality. To test this proposition, in the ACIAR seedling enhancement project, growth performance is being compared in a planting trial involving seedlings raised from *Gmelina arborea* seed imported from Costa Rica along with seedlings from unimproved local seed sources and cuttings from local 'plus' trees. Defective seedling root systems may also lead to lack of wind-firmness in outplanted seedlings. Several instances of windthrow have been observed by the authors with *Acacia mangium* on Leyte Island, an area subject to frequent typhoons, to which poor taproot development may have contributed.

Table 3 Causes of low quality seedlings

Seedling condition	Causes
Low seedling genetic quality	Only unknown and unimproved genotype seeds or wildlings available
	Collection of seed from inferior mother trees
Defective root system (J-rooting, coiled roots, severed tap root)	Containers placed on ground rather than raised shelves
	Using pots without root trainers (e.g. polybags, jam tins)
	Poor dibbling and potting out procedures
	Collection of wildlings, especially advanced ones
Slow growth	Inadequate water quantity or poor timing of application
	Poor composition of the potting mixture and lack of fertilizer
	Too much or too little shading
	Pest or disease damage
Weak seedlings (lanky, etiolated)	Poor composition of the potting mixture
	Too much or too little shading
	Poor nutrition, pest and disease control, watering
Seedling condition leading to poor performance on outplanting	Weak seedlings from nursery
	Outplanting wildlings before recovery of the root system
	Lack of sun hardening
	Deformed or severed roots
	Failure to discard weak or overgrown seedlings

Table 3 sets out some probable causes for low seedling quality, in terms of genetic quality and physical state of seedlings. Destructive testing of seedlings on Leyte Island has revealed a high prevalence of seedlings with defective root systems—including J-rooting and coiled roots—in government as well as private and community nurseries (Gregorio et al. 2004b). Where seedlings are grown in polybags or recycled tins on the ground, the tap root is frequently damaged on uplifting the seedlings. Similarly, when wildlings are used—which is common for production of mahogany planting stock—there can be considerable root damage, particularly for larger wildlings.

Poorly grown and weak seedlings can also arise from poor nursery design (as demonstrated by Surata and Butar Butar in this issue), and poor nursery practice, for example with regard to potting mix, shading system, nutrition, watering, seedling protection and sun hardening. Often there is inadequate rogueing in nurseries of weak or overgrown seedlings.

General Seedling Nursery Problems

A number of general problems can be observed in the nursery sectors in developing countries, some of which are set out in Table 4. Genetic quality of forest reproductive materials is often low, with a lack of support facilities such as seed orchards and an efficient seed supply pathway. Often there is a narrow range of seedling species available, with a lack of native species of high timber quality. In

Table 4 General problems of the nursery sector

Problem area	Specific problems
Low genetic quality of available germplasm	Local strains of exotic species are of low genetic quality in relation to growth rate or form
	Lack of seed orchards
	Lack of a well established and efficient seedling pathway
Narrow range of species base of seedlings	Unavailability of seed, especially of indigenous species (including dipterocarps)
High reliance on exotic species	Difficulties in producing seedlings of native species (obtaining seed, germinating, propagating clonally)
Industry lack of knowledge in seedling production	Limited research capability by government, research institutions and the private sector
	Lack of technology transfer to nurseries
Lack of skills in the nursery sector	Lack of training facilities
Lack of markets and profitability	Low tree planting activity
	Lack of knowledge by smallholders about the importance of using seedlings of high quality (both genetic and physical)
	Smallholders are unwilling or unable to expend cash on seedlings
	Inability to produce some of the species in high demand
	Potential buyers unaware of the existence of the nursery
	Potential buyers lack transport to visit nursery or collect seedlings
Regulatory issues	Crowding out of private nurseries in seedling markets by competition from governments seedling supplies
	Instability of policies on seedling production
	Quality standards for contract seedling production
	No incentives for nurseries to produce high quality seedlings

general, the level of research into improving seedling production and of technology transfer is low, as is the amount of skills training.

Various problems can lead to low financial viability of private nurseries. Smallholders may have low demand for seedlings from commercial nurseries, i.e. low willingness or ability to pay, arising from low involvement in the market economy, and ability to grow their own seedlings of some of the more widely grown species. Smallholders also lack of knowledge about the importance of using high quality seedlings, this being a major factor limiting the market demand for higher-priced high quality seedlings. The nurseries may not be able to produce seedlings of some of the tree species that smallholders would like to grow. In terms of accessibility of nurseries to potential customers, there may be a few large nurseries, distant from smallholders, who lack knowledge of where to obtain seedlings and lack transport facilities to collect them.

While market failure may lead to low seedling demand, government or regulatory failure may also be influential. Like private nurseries, government nurseries often provide seedlings of a limited range of species only, usually, dominated by exotics.

Frequently, government seedling nurseries (e.g. DENR and LGU nurseries in Leyte, Philippines) as well as some nurseries operated by private companies, provide free or subsidized seedlings to smallholders. This may undermine the seedling market of small private nurseries, as observed by Gregorio et al. (2006). A similar problem has arisen in Nigeria, where Babalola (this issue) observed that government institutions produce a high quality and quantity of forestry and horticultural seedlings which command high demand, thereby *crowding out* the small-scale private enterprises. The extent of this crowding out warrants further research.

Governments sometimes implement major reforestation projects, which generate high activity in seedling production to meet planting targets, with seedling quality as a subservient objective. It has been noted in the Philippines that survival rates of planted seedlings between 1960 and 1996 rarely exceeded 50% (Sy 1998). While there are various reasons for losses of young trees, including wildfires, windstorm events and livestock damage, low seedling quality is often a contributing factor.

Contracts from government to produce seedlings—for example associated with government support for community forestry projects—while highly valuable for initiating nursery operation, may be short-lived, and lead to unexpected financial failure or nurseries, and disillusionment of private and community nursery operators. If seedling production is contracted out by government, and seedling batches are accepted on the basis of a height criterion, this can favour the collection of wildlings and a short holding period by the contractor, often without full recovery of root systems before acceptance by government.

Measures to Improve Seedling Production Systems

The above review of constraints and problems suggests a number of measures which could improve the seedling quality and financial viability of forestry nurseries, and particularly small-scale private nurseries. A critical factor is improved access to resources for nursery operations, including land, finance and high quality germplasm as well as improved technology (Table 5). There would appear to be considerable scope for improved access to superior trees, in terms of form and genetic quality,[4] for example through tree breeding or seed imports.

Provision of technical information, and training (capacity building) in nursery operation and financial management, could make a substantial contribution to improved financial performance of seedling nurseries. This is not to suggest that small-scale nurseries should attempt to mimic the operation of industrial nurseries, particularly those in developed countries, but rather that they should adopt appropriate low-cost technology. Such technology might for example include

[4] As defined by Helms (1998), a *superior tree* is one having 'Genetics phenotypically better than the average of the population but not yet tested for genetic worth …' (p. 180), a *plus tree* is 'A tree selected on the basis of its outstanding phenotype but not yet clonally or progeny tested …' (p. 138), and the term *elite* applies to 'A tree, stand or group of genotypes verified by appropriate testing as being genetically superior or desirable for a specified environment and propagation system. …' (p. 55).

Table 5 Measures required by forestry nurseries to improve seedling production and financial performance

Problem area	Remedy
Resource availability to nurseries	Availability of land, finance for expansion adoption of new and technology, access to information
Availability of planting material of high genetic quality	Access to high quality seeds of high quality genotypes, e.g. through identification of superior trees, establishment of seed orchards and seed centres, seed imports
	Certification of seeds and seedlings
Improved nursery management systems and skills	Training in nursery management activities (e.g. seed storage and germination, through to hardening off prior to seedling sale or delivery)
	Raising seedlings off the ground (on steel mesh or bamboo strip shelves)
	Access to cuttings of difficult to grow (including dipterocarp) species
Access to new technology	Technology dissemination including training in the use of new seedling production technology
	Availability of appropriate clonal technology (e.g. hedge garden establishment and dry misting), and training in its use
Improving financial performance	Support rather than competition from government nurseries
	Growing certified forest reproductive materials, which may be mandatory for sales to some buyers and particularly government agencies
	Training in financial management

grafting (particularly for fruit species) and non-mist clonal propagation. There may be lessons to be learned from studying traditional methods of seedling production, as discussed by Roshetko and by Bernaldez and Mangaoang in this issue.

In that smallholders typically lack cash funds and have a low willingness to pay for forestry seedlings, low seedling prices (requiring low-cost efficient production) and tapping in on particular market segments (e.g. fruit trees, ornamentals) may be keys to nursery financial success or at least survival. The viable technology and market access keys suggested by Byron (2001) to success for smallholder forestry may also be relevant to seedling production.

Policy Implications for Nursery Seedling Production

What is needed to improve seedling production and distribution systems? What initiatives can be undertaken by government, industrial foresters, researchers and smallholders to bring about this improvement? Some suggestions are made in Table 6.

Table 6 Measures which may be undertaken by government, industry and research institutions to improve seedling production systems

Type of measure	Examples
Improving resource availability	Providing finance for nurseries to function or expand
	Making land available for seedling nurseries
	Improving the availability of skilled nursery workers
Research and development in improved seedling production technology	Development of appropriate techniques for small-scale nurseries, e.g. seed storage and germination methods, improved seedling containers, raised shelving systems, watering, non-mist cloning
Providing nurseries with access to improved germplasm	Plant breeding, establishment of seed orchards and seed banks, importing seed of genetically superior varieties
	Support for a seed supply chain or pathway
Provision of extension and training for nursery operators	Assistance in the design or nurseries, including water supply, shading and raised seedling shelving
	Training in seed collection, storage and germination
	Training and extension in the various tasks in seedling production (preparing potting mix, pricking out and potting up, seedling nutrition and protection, hardening off)
Improving seedling markets	Reducing direct market competition with private nurseries in seedling supply
	Assistance in obtaining germplasm from a wider variety of species, including native species
	Assistance in obtaining improved germplasm

The Role of Government in Making Resources Available for Small-Scale Nurseries

As well as being a seedling producer, government can play an important role in assisting private nurseries, and in assisting smallholders to grow their own high quality seedlings. In that lack of land availability is often a constraint to nursery construction or expansion (as reported by Babalola and by Ahmed et al. in this issue), governments can play a role in making land available to nursery operators. Similarly, they can assist in improving access to finance and to skilled labour.

The Role of Government in Making High Quality Germplasm Available for Small-Scale Nurseries

As noted by Nasayao (2007), government can play an important role in provision of high quality germplasm, including the establishment of seed orchards. In some countries, a well developed seedling collection and distribution system exists, examples being Vietnam (MARD 2006, Department of Forestry and DANIDA 2007) and Indonesia (Rosethko et al. 2004, this issue). The scale of nursery seedling production and hence seed demand has to be high for such a pathway to operate

effectively. Where the private sector lacks the capability, government and industry can provide leadership in development of effective seed pathways which can supply high quality seed to small nurseries and perhaps directly to smallholders. In terms of species choice, differences of opinion exist concerning the role of native tree species. In practice, the short-rotation species, which may not produce the highest quality timber, are the most widely grown in south-east Asia, including eucalypts, acacias and gmelina. However, there are sound reasons for considering native tree species, many of which have higher timber quality and greater environmental benefits, but present greater difficulties in seedling production.

The Role of the Private Sector in the Supply of High Quality Germplasm

Timber companies sometimes play a role in the seed supply chain, to the benefit of private seedling nurseries, both as a 'good neighbour' policy and with a view to having access to a greater timber supply in the future. This is the case in Mindanao in the Philippines (D. C. Cacanindin 2008, pers. comm.). Group action by smallholders can also lead to improved germplasm availability, particularly when supported by a research agency, as demonstrated by activities of the Agroforestry Tree Seeds Association of Lantapan (ATSAL) in the Philippines, reported by Catacutan et al. (this issue).

Promotion of Production Methods to Achieve High Seedling Quality

There would appear to be considerable scope for improvement of management practices in seedling nurseries, with regard to nursery design including shading system, seed storage and germination, formulation and sterilization of potting mix, pricking out and potting up, measures to prevent root deformation in potted seedlings, watering, nutrition, seedling protection, regueing, discarding overgrown seedlings, and hardening off. This suggests the need for promotion of quality control or *best management practice* within nurseries. Deformed root systems typically arise from growing seedlings in polybags, placed on the ground, which suggests that local production of improved containers (e.g. pots with ribs for root training) and use of raised shelving and air-pruning of roots may be warranted. There would appear to be a role for applying traditional knowledge in seedling production, where it can be shown to be effective, as well as new technology when this is proven advantageous.

Improving the Financial Performance of Seedling Nurseries

In that marketing seems to be a major weakness in the seedling nursery sector, it may be desirable to place high priority on improving seedling marketing systems. This could involve governments taking a greater role in working cooperatively with private nurseries, rather than competing with them to provide seedlings. One possible role for government is to produce seeds, seedlings or cuttings of difficult-to-grow species (often native species), and providing reproductive materials of these

species to private nurseries at low cost. Contracting out seedling production to community and private nurseries provides a means of supporting these nurseries and increasing their financial stability, and to the extent that private operators are more cost-effective than government may reduce seedling production costs. Under this arrangement, government could play a guiding role in relation to quality control.

Production of Seedlings by Individual Tree Farmers

The question arises as to whether tree farmers should be encouraged to produce their own seedlings. This is technically feasible, and could make available much larger quantities of seedlings, at low cost, without the distribution problems of seedling nurseries. However, maintaining quality presents difficulties, and there is likely to be a bias towards easy-to-grow exotic species.

Research, Development and Technology Transfer Activities

In developing countries, Research and Development is an area heavily reliant on the support of government, aid agencies and NGOs. Improvement in seedling production technology can be viewed as a component of forestry development, for production and environmental benefits, with public expenditure justified by non-market benefits. Target areas include improvements in species availability, genetic quality and nursery practice, including improving the skills base. A variety of methods are available for transfer of new nursery technology and management information, so as to improve the capability of nursery operators and staff. Some options include training courses, site visits by extension staff, bus tours to demonstration sites, broadcast information through television and radio, and distribution of training packages (e.g. video cassettes and disks) and printed materials.

Concluding Comments

Many of the problems experienced in seedling production can be observed in a number of developing countries, and identifying these problems can be helpful in informing forest policy. Forestry seedling nurseries are easy to set up in these countries, but unfortunately typically produce low quality seedlings and often fail financially in a short time. High failure rates of new businesses is common in market economies, and it is not clear whether the high failure rate of private forestry nurseries is a symptom of a poor system or a natural evolutionary state. While short operating life is probably a natural state for specific-purpose nurseries such as those set up for community forestry projects, in many cases lack of seedling sales contracts and of regular demand seems to be the reason for failure.

Various measures are available to improve seedling quality and nursery financial performance. There appears to be a threshold plantation forestry industry size for some nursery sector measures, such as seed pathways and use of tissue culture for

clonal propagation. On the other hand, some forms of advanced technology, including non-mist clonal seedling production (DENR 2003), may be viable even in small rural communities.

There would appear to be strong justification for government support in seedling production, particularly in countries or regions with a fledgling plantation forestry industry, due to the positive externalities of timber production and revegetation programs. Measures such as genetic improvement of plantation species, provision of free seedlings, and extension activities including demonstrations and site visits are means of promoting the interest of smallholders in forestry. A difficulty arises where provision of free seedlings by government crowds out private nursery enterprises. Hence, where there is potential for private nurseries to be financially viable, it may be a preferable policy for government to assist private nurseries rather than compete with them.

Periodic large-scale tree planting schemes of governments provide a major stimulus to seedling nursery operations during the planting phase. However, this demand is unlikely to be sustained in the longer term, when many nursery casualties can be expected. Further, the strong emphasis on numbers of seedling produced can divert attention from seedling quality. In terms of promoting a sustainable industry, it may be desirable to move away from seedling quantity targets to seedling quality targets. In general, there does appear to be a need for constancy of government policy with regard to seedling production, and adoption of long-term seedling quality improvement programs.

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